CONSTRUCTING RESILIENT WETLANDS AT POPLAR ISLAND: A COMPARATIVE CASE STUDY

by
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Executive Summary

Sea level rise has been impacting coastal wetlands along the Chesapeake Bay since the last century. This report looks to evaluate the key lessons learned at Poplar Island in order to develop a plan for Eastern Neck Island's diminishing wetlands. In the report, background information on Poplar Island and Eastern Neck Island was researched. It was concluded that the key lessons learned from Poplar Island were related to high marsh to low marsh ratio, elevation of high and low marshes, incorporation of ponds for increased species diversity, and inclusion of dikes. The report completes an in-depth analysis of each of those lessons and applies them to Eastern Neck Island. It was determined that a new high to low marsh ratio should be implemented so that the low marsh and high marsh have an even percentage of the area. A higher elevation of the marshes is needed to ensure low coastal erosion from rising tides. Ponds can be beneficial for species diversity; however, it is important to determine a pond area favorable to the wetlands to not increase erosion. Finally, dikes can be used to retain sediment and build accretion within the wetlands. This report incorporates many solutions to developing resilient wetlands which the developers of Eastern Neck Island restoration plan should include in their development plan.

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Introduction

Sea levels in the Chesapeake Bay have been rising the last few centuries and will continue to rise in the future. This will continue to impact many coastal areas in the Chesapeake Bay, including the islands located within the Bay. Over the past century and a half, Poplar Island's land area has decreased by more than a thousand acres due to sea-level rise and erosion. Because of this loss, federal and state agencies started reconstructing the island to bring back lost habitats. However, scientists have discovered the wetlands that have been constructed are being threatened by rising sea levels. Therefore, for the last few years, the constructed wetlands have been studied and new techniques have been developed to make constructed wetlands more resilient to anticipated sea-level rise. Another island, Eastern Neck Island, also located within the Chesapeake Bay, is currently being assessed to determine how to best implement the construction of wetlands to restore local habits lost due to land loss from sea-level rise. The purpose of this paper is *to analyze Eastern Neck Island to determine how to apply the lessons learned from Poplar Island to design and construct resilient wetlands.*

Background Research

Climate change as well as glacial rebounding is causing sea level to rise within the Chesapeake Bay region, which is causing erosion along the coast. Glacier rebounding is when the Earth's crust begins rising after glacial ice sheets recede. This occurs because the crust is no longer under the pressure of the ice sheets[i]. The erosion from rising sea levels can impact the surrounding habitats. In order to restore the habitats lost on the island, wetland development at Poplar Island has occurred. Marine ecosystems depend on the rate of sea level rise, amount of sediment, and tidal range[ii]. Therefore, these wetlands have to be adapted to account for sea-level change.

This paper will focus on why there is a need to develop resilient wetlands at Poplar Island and will analyze four key lessons learned and apply them to Eastern Neck Island's wetland development. The key lessons learned that will be analyzed are:

- Increasing the high marsh to low marsh ratio
- Increasing the elevation of high and low marshes
- Incorporation of ponds for increased species diversity
- Inclusion of dikes to retain sediment levels and build accretion

Poplar Island Background

Poplar Island is an island located in Talbot County, Maryland in the Chesapeake Bay **(Figure 1)**[iii]. "Since 1847, erosion driven by wave action and sea level rise has resulted in the loss of 85 percent of the Poplar Island landmass." Due to this the U.S. Army Corps of Engineers first conducted an Integrated Feasibility Report in 1996 which included an Environment Impact Statement (EIS) to determine how to restore Poplar Island to its 1847 area of 1140 acres[iv]. The Integrated Feasibility Report recommended an Environmental Restoration Project Plan focusing on wetland and upland development. After the original

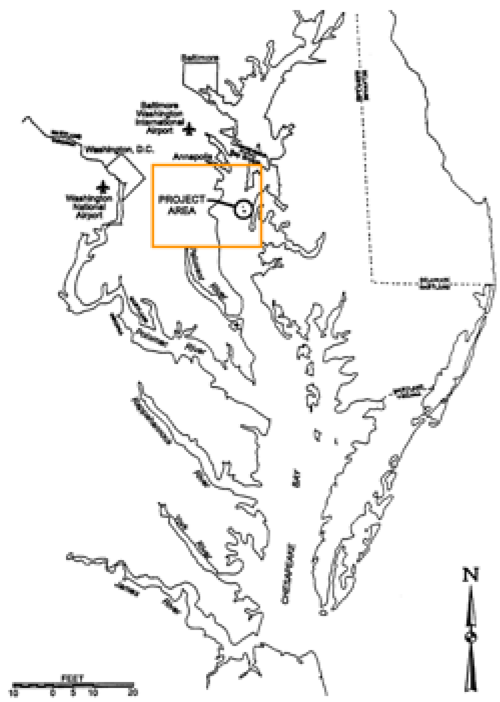

Figure 1: Poplar Island's Location

acreage was successfully constructed, the feasibility of adding an additional 575 acres was studied in the 2005 General Re-Evaluation Report and Supplemental EIS[v]. The initial plan called for creating 50% wetlands and 50% uplands and dredging sediment material from the approach channels to the Port of Baltimore to reconstruct the island. However, the 2005 General Re-Evaluation Report and Supplemental EIS recommended expansion and a new ratio was suggested for the additional area: 29% wetlands (80% low marsh and 20% high marsh), 47% uplands, and 24% open water embayment[vi]. Since one of the missions of the U.S. Corps of Engineers is to keep the navigation channels within the Chesapeake Bay cleared, they decided to use the dredged material from the channels to restore the island within the upland and wetland areas[vii]. Within the last few years, project managers and scientists at Poplar Island are having to deal with a greater rising sea level. Thus, the current goal of Poplar Island's scientists is to develop wetlands that are resilient to sea-level rise.

Eastern Neck Island Background

Eastern Neck National Wildlife Refuge (NWR) is an island located in southern Kent County, on the Eastern Shore of Maryland **(Figure 2).** "Since 2005, the refuge has been managed as part of the Chesapeake Marshlands National

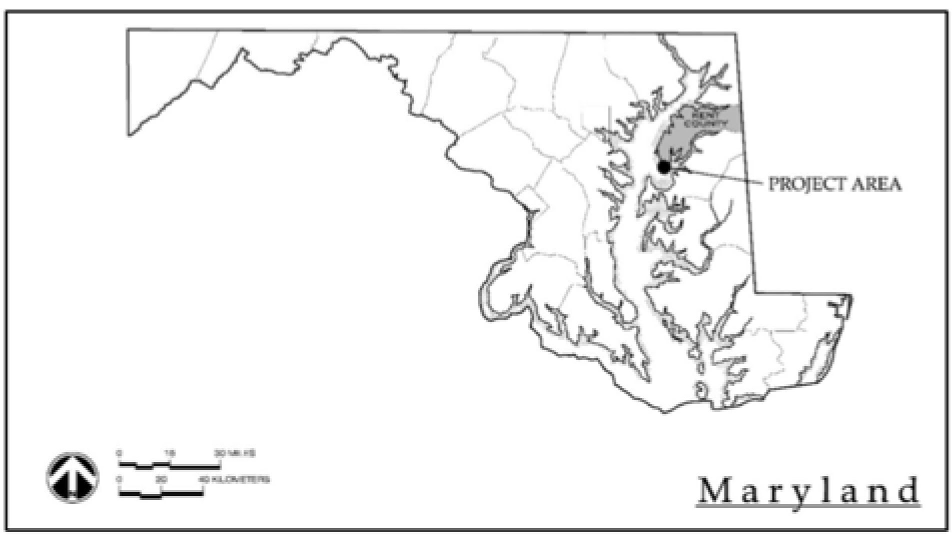

Figure 2: Location of Eastern Neck Island

Wildlife Refuge Complex". Coastal erosion has been occurring throughout the Chesapeake Bay. This has caused tidal marsh habitats and aquatic vegetation to be vulnerable. "The Eastern Neck National Wildlife Refuge sits squarely within the Atlantic Flyway, an important corridor of wetland habitats for migratory birds" [viii].

In 2018 the U.S. Fish and Wildlife Service had an Environmental Assessment prepared to determine the possible environmental effects of erosion along the coast of Eastern Neck Island. From that report a Restoration Project was suggested to reduce erosion along its southern shoreline. The specific goals of the Eastern Neck Island's Restoration Project for the southern shoreline are to:

1. *"Slow the loss of existing tidal marsh and protect important submerged aquatic vegetation (SAV) habitats"*
2. *"Restore tidal marsh where possible and maintain ecological integrity of shoreline and nearshore habitats"*

Figure 3: Eastern Neck Island Project Area for Severe Erosion

The southern shoreline is at a higher risk for erosion because of the shore's outline and impact from waves **(Figure 3)**[ix]. As with Poplar Island, Eastern Neck Island is planning to import dredge material to restore the marshes. Sixteen thousand cubic yards of dredge material will come from the Kent Narrows Channel[x].

Methods

Introduction

For this report Poplar Island was used as a comparative study to Eastern Neck Island in order to develop sea-level rise resilient wetlands. First, the Chesapeake Bay was analyzed to determine the projected sea level rise and outcomes as well as the projected change in tidal range. Then, data was taken from Poplar Island and Eastern Neck Island for current land and wetland area. The overall land and wetland areas were compared to determine if the key lessons learned were appropriate for Eastern Neck Island. Next, the data was analyzed and researched to determine how Eastern Neck Island could incorporate the key lessons learned to increase habitats and restore land area lost. In order to complete this project project managers for Poplar Island that work for the U.S. Army Corps of Engineers, as well as scientists from the University of Maryland Center for Environmental Science were reached out to in order to learn more about how Poplar Island was adapting to sea level rise and for guidance on determining applicable research papers. In addition, scientists from the U.S. Fish and Wildlife Services and the Maryland Department of Natural Resources were contacted to understand more about the work currently being done at Eastern Neck Island. Finally, diagrams were developed to show where and how Eastern Neck Island could implement the lessons learned from Poplar Island.

Data

Overview of Chesapeake Bay

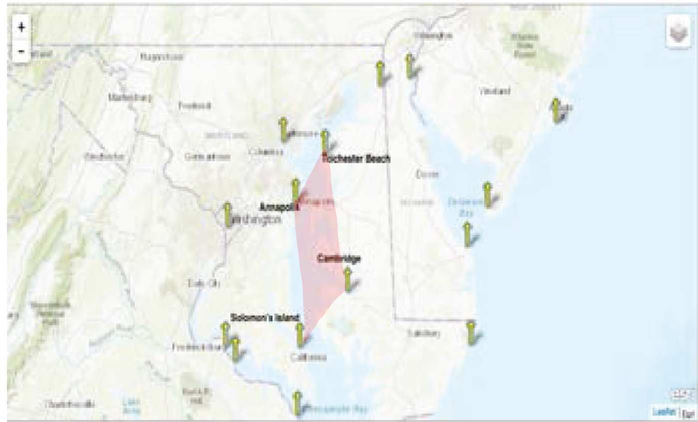

Figure 4: Map of Chesapeake Bay Sea-Level Stations

When looking at resilient wetland development, it is important to determine the rate of sea-level change. **Figure 4** shows the locations where sea-level measurements were taken at stations along the Chesapeake Bay. The stations were chosen because they bracket the area of study—Poplar Island and Eastern Neck Island. Those stations—Tolchester Beach, Annapolis, Cambridge, and Solomon's Island sea level measurements can be seen in **Figures 5-8**. These measurements were taken from NOAA for the years 2000-2020. The monthly sea levels were averaged in order to plot one data point for each year. This was done because throughout the year the tides change with the moon, therefore just one month couldn't be used for each year. Next, it is imperative to determine the projected change in sea level in order to prove a need for a change in wetland design. Therefore, a linear forecast model was developed based on the data in **Figures 5-8** taken from NOAA for the last twenty years[xi].

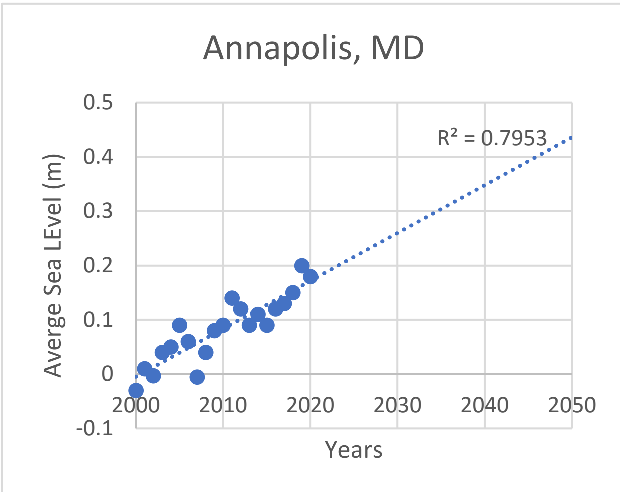

Figure 5: Graph of Average Sea Level at Annapolis, MD from 2000-2020 with linear projections for 2021-2050.

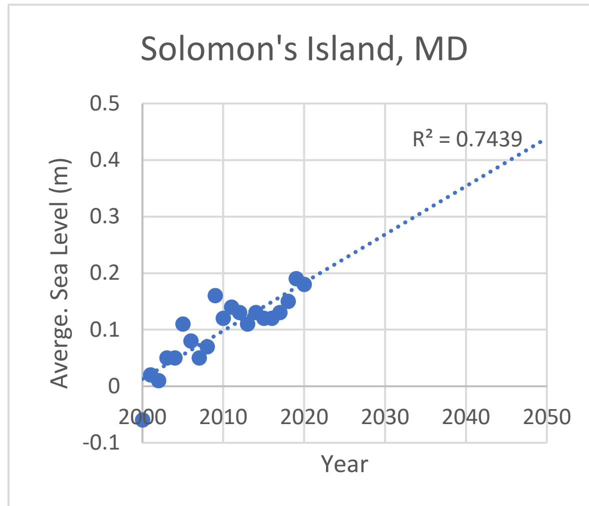

Figure 6: Graph of Average Sea Level at Solomon's Island, MD from 2000-2020 with linear projections for 2021-2050.

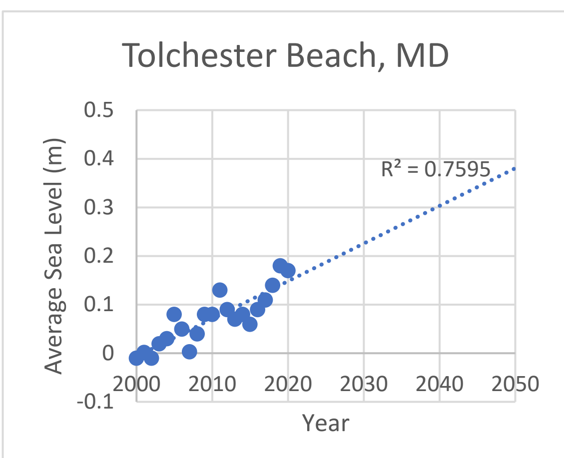

Figure 7: Graph of Average Sea Level at Tolchester Beach, MD from 2000-2020 with linear projections for 2021-2050.

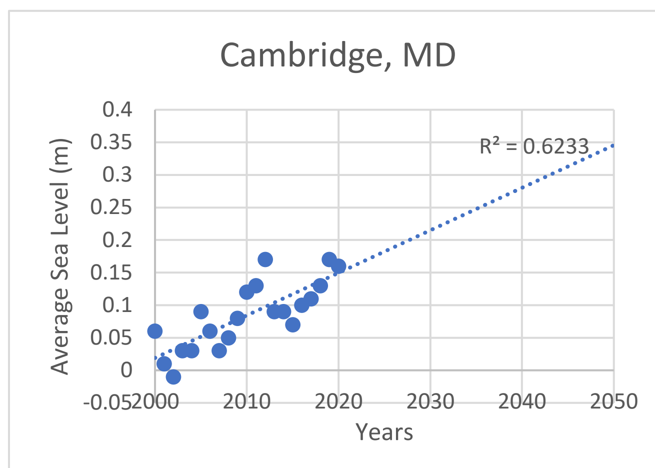

Figure 8: Graph of Average Sea Level at Cambridge, MD from 2000-2020 with linear projections for 2021-2050.

Sea-level rise has caused coastal erosion as well as an increase in tides. **Figure 9** shows the projected tidal increase for the Chesapeake Bay with one-meter increase of sea level rise[xii]. If the Chesapeake Bay's sea level continues to rise many of the coastal communities will be inundated with water. **Figure 10** shows how an increase in 0.3 meters could affect the Chesapeake Bay coastline, while **Figure 11** shows the effects of a 0.6 meters increase. The shade of blue shows the depth of water ranging from low depth to high depth[xiii].

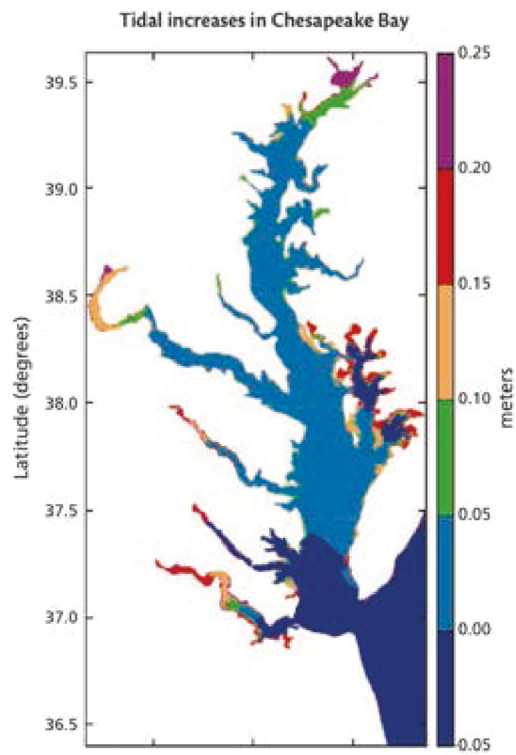

Figure 9: Tidal Projections for Chesapeake Bay

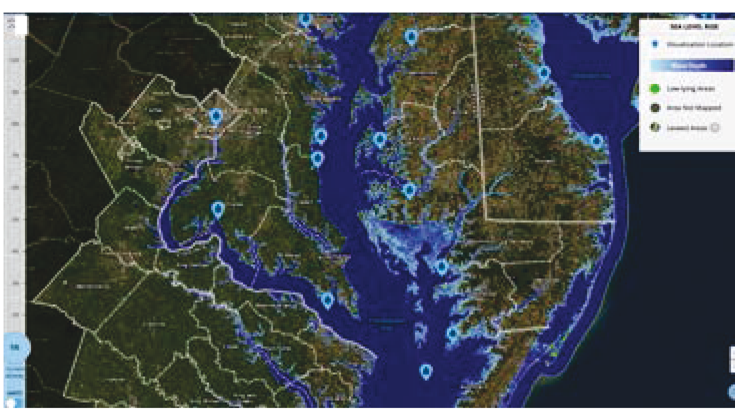

Figure 10: One-foot sea level change in the Chesapeake Bay. The range of blue shows the water depth (light blue, low depth and dark blue, high depth).

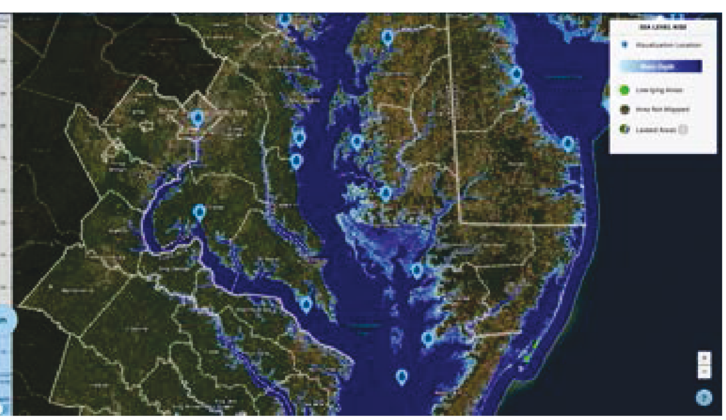

Figure 11: Two-foot sea level change in the Chesapeake Bay. The range of blue shows the water depth (light blue, low depth and dark blue, high depth).

Poplar Island

Land Area

Poplar Island has experienced a rise in sea-level for thousands of years, as well as increased tidal ranges. This has eroded Poplar Island's coast dramatically. **Figure 12** shows the amount of land lost for Poplar Island as well as additional locations within the Chesapeake Bay from 1650-2000[xiv]. For the purpose of this report those, the information shown for Poplar Island is of greater importance.

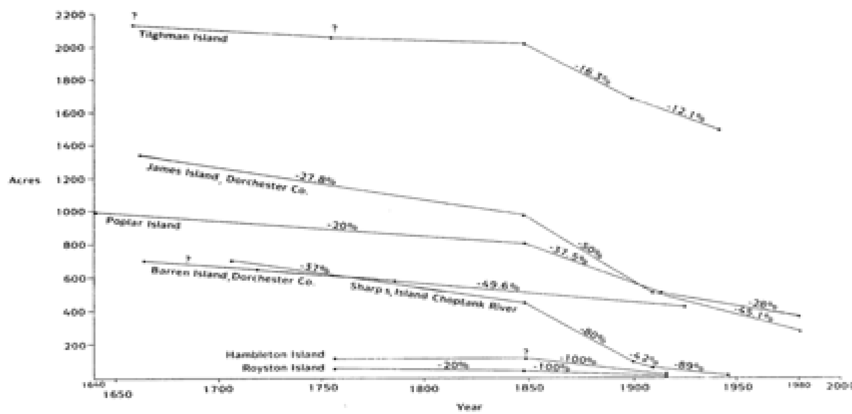

Figure 12: Land lost in acres from 1650-2000 for Poplar Island and additional locations in the Chesapeake Bay.

Wetland area

In addition to overall land loss due to sea level rise, wetland loss from increasing tide levels is an effect as well. A rise in sea level causes the tide levels to increase, which leads to wetland areas becoming flooded more frequently. Below, **Figure 13(a)** shows the arial view of Poplar Island with cells identified, **(b)** shows low marsh area for those cells, and **(c)** shows high marsh area for those cells[xv]. The high marsh accounts for 20% of the cell, while

Figure 13 (a) Arial view of Poplar Island identifying cells.

the low marsh accounts for 80%. When the project started, the separation between high and low marsh was at an elevation of 0.54 meters. At this separation, the high marsh species are planted above the line and the low marsh planted below the line. However, there is some overlap between the species to allow for movement. The high and low marsh separation is currently at an elevation of 0.7 meters, due to the increase in the height of the tides. Then, the upland area starts at elevations > 1.0 meters. The high to low marsh separation line is determined by the change in vegetation from spartina alterniflora to spartina patens, which roughly matches the average high tide in the area. Over time, the high marsh-low marsh break point is adjusted according to the increase in the average high tide level[xvi].

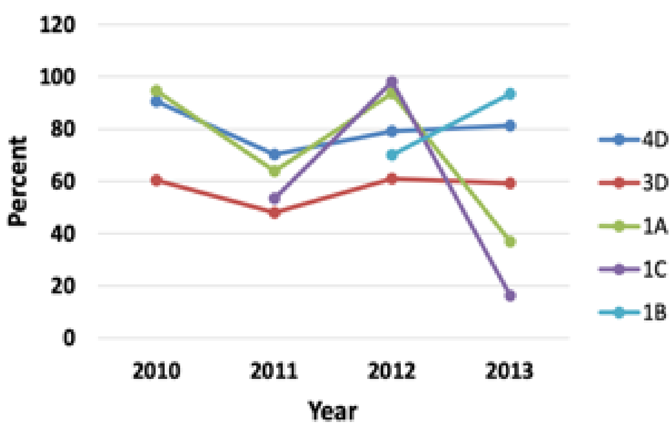

Figure 13 (b) Low marsh area cover for Poplar Island cells.

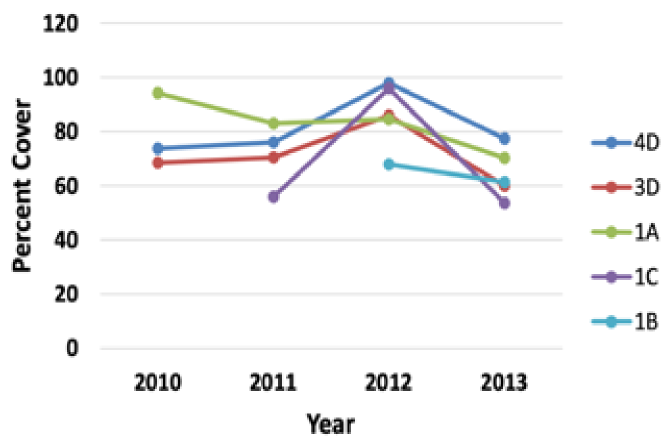

Figure 13 (c) High marsh area cover for Poplar Island cells.

Eastern Neck Island

Land Area

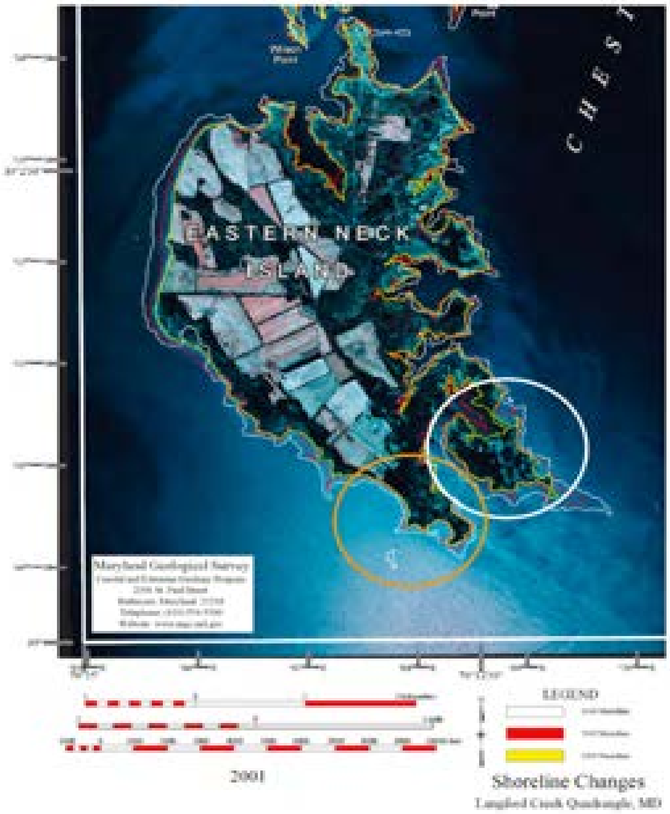

Figure 14: Eastern Neck Island Shoreline Changes (white: 1846, red: 1942, yellow: 1992)

Eastern Neck Island's coast has been eroding over time since sea levels have been rising. In 1846, surveyors were able to accurately measure the shoreline for the first time. **Figure 14** shows an overview of erosion occurring along Eastern Neck Island. More recent data has been collected for areas within the white and orange circles shows in **Figures 15 (a) and (b)**[xvii]. The blue lines indicate the most recent data collected from 2013, while the green lines and red lines are from 2005 and 1992, respectively.

Figure 15 (a): Eastern Neck Island Shoreline Changes for orange circle

Figure 15 (b): Eastern Neck Island Shoreline Changes for white circle.

Wetland Development

Eastern Neck Island currently has 860 acres of mostly brackish marsh habitat. "Brackish marshes are transitional wetlands between tidal freshwater systems and salt marshes."[xviii] **Figure 16** below, shows the marsh area in purple for Eastern Neck Island[xix]. As of 2018, the Queen Anne's County Department of Parks is "soliciting proposals for engineering services to obtain permits, develop design, prepare bid documents, and perform contact administration, inspection and other services during construction for maintenance dredging of the Kent Narrows – Chester River Navigation Channel and placement of material onto Eastern Neck Island shoreline for marsh creation[xx]." This channel is under the jurisdiction of the U.S. Corps of Engineers. After speaking with project managers at the Corps, there are currently not any projects involving Eastern Neck Island. The last known project the Corps was involved with at Eastern Neck Island was in 2008. However, the Department of Natural Resources did dredge sandy material from Kent Narrows Chester River Channel and placed the material along the northwest shoreline[xxi].

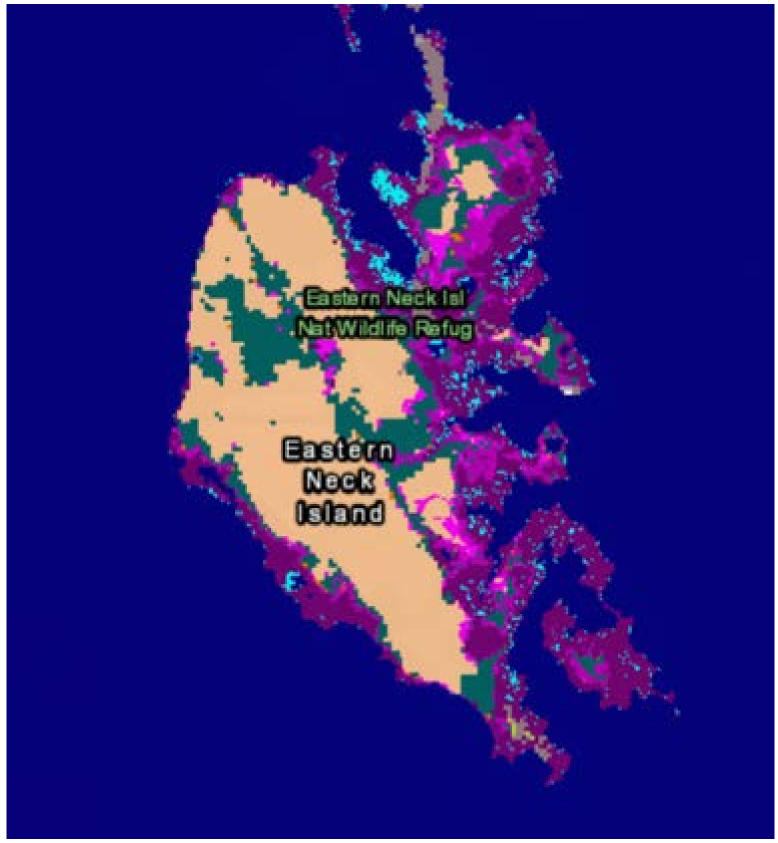

Figure 16: Eastern Neck Island Marsh Area (shown in purple)

Analysis

Introduction

The purpose of this report is to investigate locations that are being affected by rising sea levels to determine if those areas may benefit from the construction of wetlands in order to restore local habitats. The method for choosing Eastern Neck Island was determined by locating areas along the Chesapeake Bay that are being adversely affected by high levels of sea level rise. Using the projections taken in **Figures 5-8**, the anticipated sea level for 2050 is 0.4 meters, a rise of approximately 0.22 meters. According to Maryland's sea level rise projections, sea level is likely (66% probability) to rise 0.24 to 0.48 meters from 2000 to 2050[xxii]. Projections made specifically for the Chesapeake Bay determined in this report, fall closely to Maryland's projected numbers. However, it is important to note for **Figures 5-8** the projections were determined based on four sea level measurement stations. However, each individual station can be influenced by separate factors such as runoff, drainage, proximity to coastline, and position along the Chesapeake Bay. Locations in the red area on **Figure 4** were looked at specifically for the development of this report. After focusing on this section of the Chesapeake Bay, the NOAA's Coastal Simulation Sea Level Rise Viewer was used to determine which locations would be analyzed. This was done using the Sea Level Rise, Marsh Migration, and Vulnerability layovers. **Figures 10 and 11** model the sea level rise projections for areas within the Chesapeake Bay. **Figure 10** shows the area with a change in 0.3 meters. At this level, there are some areas on the shoreline of the Chesapeake Bay with a high-water depth (dark blue). As the sea level is increased to 0.6 meters, shown in **Figure 11**, additional areas along the shore have a higher water level. Therefore, it was determined that areas along the shore of the Chesapeake Bay were more likely to experience greater negative effects because of sea level rise. As seen in **Figure 9** tidal projections for the Chesapeake Bay shoreline can change up to 0.25 meters in the north and 0.10-0.20 meters within its tributaries. Eastern Neck Island was found to be a location that had a high risk for vulnerability based on the models shown in **Figures 9-11**. Upon further research it was determined that this location had plans to use wetlands to adapt to rising sea levels in order to protect shorelines and increase local habitat after land loss.

Comparing Poplar Island and Eastern Neck Island

Land Area

According to **Figure 12**, from 1650 to 1850 Poplar Island lost 20% of its land area. Then from 1850 to 1915, the island lost another 37.5%. Finally, from 1915 to 2000 the island lost 45.1% of its land area. In total for the last century Poplar Island went from one thousand acres to approximately four hundred acres. In comparison, Eastern Neck Island has only seen coastal erosion along its shore. In **Figure 15** the red outline shows the shoreline from 1992, the green from 2005, and the blue from 2013. From the data one can see a steady decrease of in land area along the shoreline for Eastern Neck Island, particularly for area 4 from **Figure 15(a)** and 7, 8 and 9 from **Figure 15(b)**. As stated previously in this report, Eastern Neck Island's Restoration Plan calls for an adaptation of coastal wetlands along the Southern side of the island where these area are located.

Wetland Development

As seen in **Figures 13(b) and 13(c)** the low and high marsh area has been decreasing for Poplar Island since 2012. As sea level rises the low marsh area along the water end becomes more aquatic and begins to migrate to the high marsh area, which causes the high marsh area to migrate towards the uplands. This creates an area with a very large low marsh and a very thin high marsh. The amount of sediment and biomass within the marsh decreases due to rising tides so much so that the area is barely keeping up with sea level rise. Eventually, the wetland areas will be diminished completely[xxiii]. Most of the eastern side of Eastern Neck Island has approximately 860 acres of brackish marsh. The goal of the Eastern Neck Island Restoration Project is to restore this marsh area that has been lost due to erosion and sea level rise. As seen in **Figures 15(a) and 15(b)** most of the shoreline lost in the Southern part of the island is marshland.

Results – Application to Eastern Neck Island

Marsh Ratio

First, the research team at Poplar Island determined that the ratio of high to low marsh was insufficient for the anticipated increase in sea level. This is because as sea levels continue to rise the low marsh areas become inundated too frequently, leading to low marsh areas becoming non-existent. Marsh drowning can occur if the area cannot generate enough accretion compared to relative sea level rise rates[xxiv]. For future wetland creation at Poplar Island, a different ratio of 50% high marsh and 50% low marsh is being researched. However, currently a new ratio of 78% low to 22% high has been used for the recently developed cell 5. Since this cell has just be developed with the last two years, data is not yet readily available. **Figure 17** below shows the location of low and high marshes within the wetlands[xxv]. A low marsh area is inundated by mean high tide, while high marsh is inundated by spring high tide. Therefore, low marshes are inundated two times each day, but high marshes are only inundated during very high tides that occur less frequently.

As mentioned in the previous section, Poplar Island's low marsh area is expanding into the high marsh because the lower portion is becoming flooded too frequently. This is leading the high marsh area to migrate towards the upland. This creates an area with a very large low marsh and a very thin high marsh. Therefore, Eastern Neck Island should focus on creating a marsh area that is 50% low marsh and 50% high marsh. This would allow the low marsh to expand with the rising sea level, but not overtake the majority of the high marsh as long as accretion within the marsh occurs.

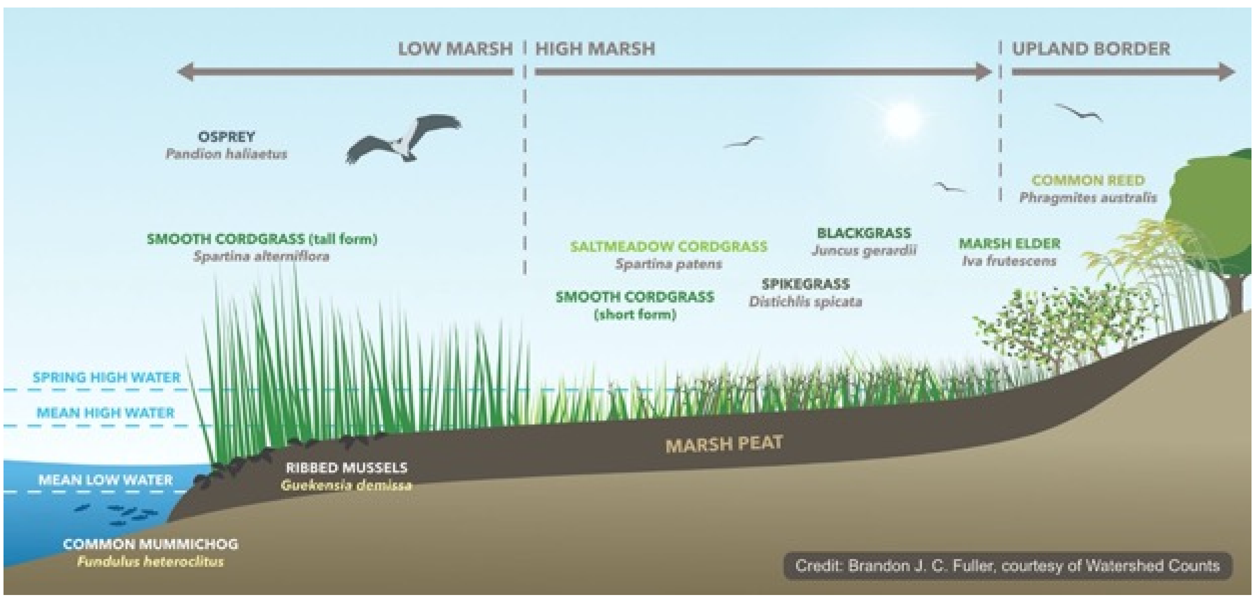

Figure 17: Anatomy of wetlands

Elevation of Marshes

Second, while it is important to have the appropriate ratio of low to high marsh, it is also important to take into account the elevation levels for each marsh type. One study suggests that the ratio of elevation to mean sea-level rise is the most important to take into consideration[xxvi].

Depending on the coastline and tidal changes, a higher low marsh and a higher high marsh are recommended so they aren't inundated too frequently due to increasing sea level.

When determining the appropriate elevation for high and low marshes, it is important to consider the relative sea level and the level of high tides. In the Chesapeake Bay the projected mean sea level is expected to be 0.4 meters by 2050. This would be an increase of approximately 0.22 meters. The projected tidal increase for this portion of the Chesapeake Bay is 0.1-0.15 meters. The current high tide average for Tolchester Beach, MD, which is in close proximity to Eastern Neck Island is 0.532 meters[xxvii]. In the next few decades Eastern Neck Island can expect to see relative sea-level rise of 0.4 meters with an average high tide of 0.63-0.68 meters. When determining the elevation for the low marsh, the anticipated average high tide of 0.63-0.68 should be used. To determine the high marsh, the average projected higher high tide of 0.75 meters should be used.

Incorporation of Ponds

Third, in order to increase fish reproduction and generate sediment accretion, ponds can be incorporated within the marsh. At Poplar Island currently there are ponds located within the low marsh areas. However, ponds have not been constructed in the high marsh area "due to concerns of stagnation leading to development of mosquito habitat and potential harmful algal blooms[xxviii]." Eastern Neck Island could also incorporate a pond to increase habitats similar to Poplar Island. A connected pond would "recover if its bed lies above the limit for marsh plant growth or if the inorganic deposition rate is larger than the relative sea level rate (RSLR)[xxix]." It is important to note that a pond would expand and start to collapse creating large amount of erosion if the deposition rate was smaller than the relative sea level rise rate.[xxx] Studies have shown that many, smaller ponds are more beneficial than one large pond. In the study, the scientists found that, "a set of ponds of small size had more species and had a higher conservation value than a single large pond of the same total area." Most species thrived in ponds that were 6–434 meters in area [xxxi].

Inclusion of Dikes

Fourth, in order to generate vertical accretion in the marsh the incoming tidal velocity must be greater than the outgoing tidal velocity to create a flood-dominant system. If this is not the case, dikes can be used to help retain sediment. When determining the type and size of the dike it is important to consider not only the velocity, but the tidal range and sediment load as well[xxxii]. One study conducted determined that a wide green dike **(Figure 18**) was best when adapting to rising sea levels. The study found that "if the marsh keeps pace with sea-level rise, the dike stays subjected to similar waves as initially. However, if the inundation depth increases as a result of sea-level rise the dike will be exposed to higher waves[xxxiii]." Therefore, the dike's height should be at a level above the tidal range. Based on sea level rise projections it was found that a clay thickness of 1.6-1.8 meters is optimal along with a height of 9-9.5 meters + NAP (Normal Amsterdam Level)[xxxiv]. The Normal Amsterdam Level or also referred to as the Amsterdam Ordnance Datum is the "reference plane for height in the Netherlands and many other countries[xxxv]." This measurement was developed because of the 1675 flood that destroyed low-lying lands. Because of that, from 1683 to 1684, the high tide was measured daily. This level became the Amsterdam level or A.P. and was used as the reference plane for future development of dikes and barriers. Centuries later the A.P. was renamed to the NAP or Normal Amsterdam Level. Currently, "all heights of land, water, dykes and tunnels are measured with respect to this plane[xxxvi]."

In order to generate vertical accretion within the marsh and keep up with rising sea levels, Eastern Neck Island should incorporate a wide green dike with the parameters suggested above.

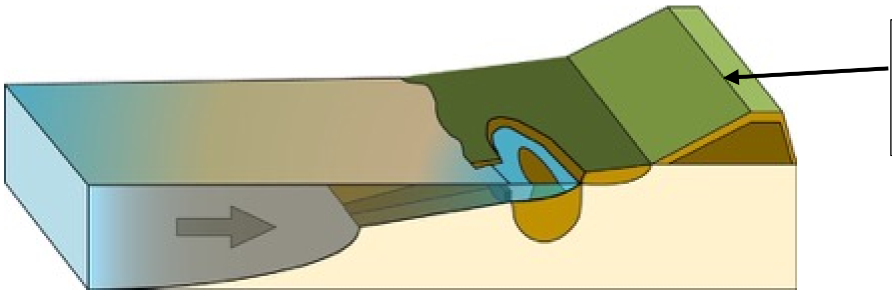

Figure 18: Example of wide green dike

Diagram of Resilient Wetlands for Eastern Neck Island

In order to show how Eastern Neck Island could incorporate resilient wetlands into their Restoration Plan, two diagrams have been developed. To do this, first, an analysis was conducted to determine the best locations of resilient wetlands. Similarly, to Poplar Island, Eastern Neck Island could implement these wetlands in stages, first starting with the areas with the highest erosion severity, then moving onto the areas with medium and lowest severity. The first diagram was constructed to show the measurements for wetlands for marsh ratios and elevations. The second diagram was developed to show the measurements for a low marsh pond in order to increase species diversity without contributing to wetland erosion.

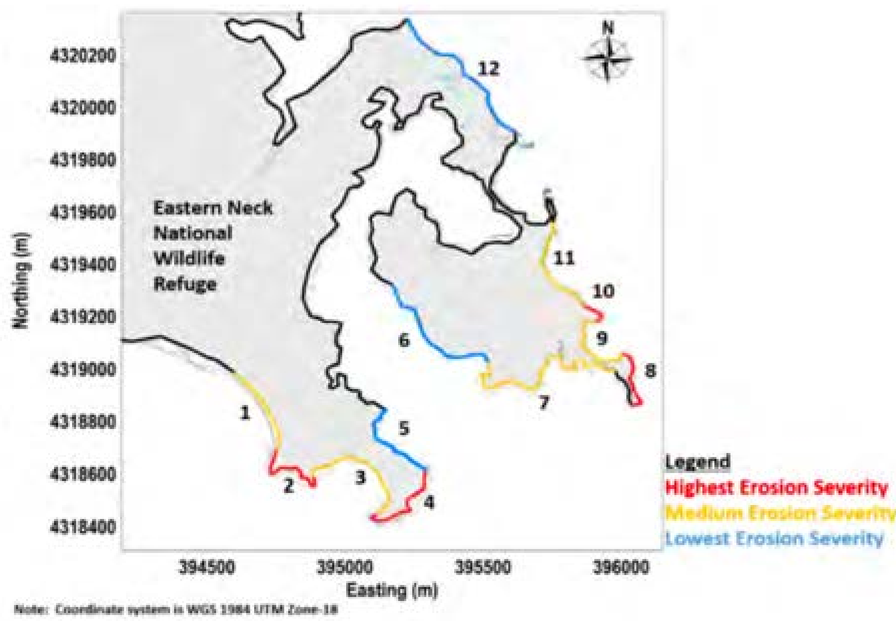

Figure 19: Erosion Severity at Eastern Neck Island

Figure 19 shows the severity of erosion along the shoreline of Eastern Neck Island. Based on this map, it is recommended that the resilient wetlands be constructed along points 2, 4, 8, and 10 because those have been determined to have the highest erosion severity[xxxvii].

Below are two diagrams showing how resilient wetlands could be constructed at Eastern Neck Island. These diagrams are based on research and data from above on high to low marsh ratios and elevations, as well as pond and dike locations. The measurements were determined by data from Poplar Island, as well as research conducted by scientists within the field.

In the diagram below (**Figure 20**) a wetland model was constructed for Eastern Neck Island. The diagram has been modified to include the key lessons learned from Poplar Island to show the measurements determined[xxxviii].

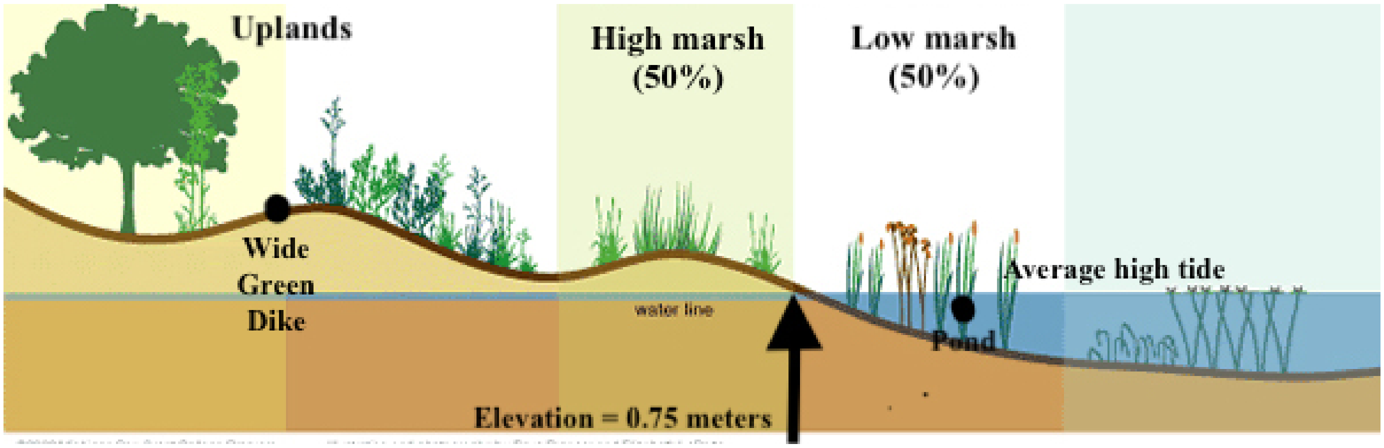

Figure 20: Diagram of constructed wetlands at Eastern Neck Island

Based on the key lessons learned from Poplar Island for the inclusion of ponds, **Figure 21**, the following diagram has been constructed to show the placement and size of a low marsh pond. A smaller open water pond with the following dimensions should be constructed along with the wetlands at Eastern Neck Island to increase species diversity. It is recommended that two ponds with the dimensions below be used in each location. The diagram has been modified to include the key lessons learned from Poplar Island to show the measurements determined[xxxix].

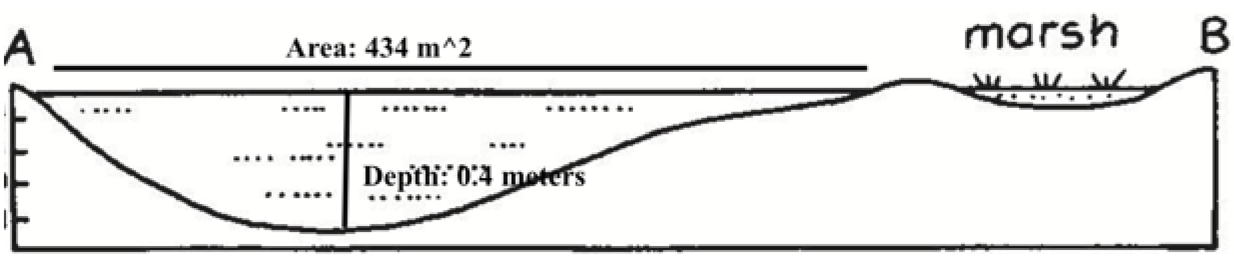

Figure 21: Diagram of constructed open water ponds for Eastern Neck Island

Discussion

Sea-level rise has been impacting coastal wetlands along the Chesapeake Bay for the last few centuries. This report evaluated the key lessons learned at Poplar Island in order to develop a plan for Eastern Neck Island's diminishing wetlands. It was determined that the key lesson learned from Poplar Island were high marsh to low marsh ratio, elevation of high and low marshes, incorporation of ponds for increased species diversity, and inclusion of dikes. This report analyzed these lessons learned with the goal to apply those lessons to Eastern Neck Island. The development plan for Eastern Neck Island was determined as such:

1. A high to low marsh ratio of 50% to 50% to allow for low marsh receding from the coast and for expansion into the high marsh area.
2. A new break point elevation between high and low marshes of 0.75 meters should be used. As the projected high tide will be 0.75 meters, the high marsh should have an elevation above this tide level.
3. Many, smaller ponds with areas of 6–434 meters squared to include species diversity [xl].
4. Dikes should be included with a thickness of 1.6-1.8 meters and a height of 9-9.5 meters + NAP (Normal Amsterdam Level- reference level)[xli].

Construction of resilient wetlands at Poplar Island has just begun in the last two years, and as such there is not yet quantitative data to determine if these key lessons learned will allow wetlands to adapt to sea-level rise. However, research as well as qualitative data from Poplar Island's project managers has shown that these measures can lead to more resilient wetlands. Therefore, these design concepts within the key lessons learned should be implemented as part of the wetland development strategy at Eastern Neck Island in order to create wetlands more resilient to sea-level change.

Conclusion

Sea-level rise will continue to impact coastal areas along the Chesapeake Bay. Throughout this report, the key lessons learned from Poplar Island were analyzed and applied to proposed wetland development at Eastern Neck Island. It has been determined that in order for

Eastern Neck Island to retain their coastal wetlands, they must take into consideration within their Restoration Plan the following: high marsh to low marsh ratio, elevation of high and low marshes, incorporation of ponds for increased species diversity, and inclusion of dikes.

This report compared Eastern Neck Island to Poplar Island because it was found that they have some key similarities and differences. Both islands are located in Chesapeake Bay on the Upper Eastern Shore in Maryland and are within close proximity to one another. In addition, both islands have wetland loss due to rising sea levels from climate change and glacial rebounding. However, Poplar Island has been almost completely re-developed because of complete land loss. Eastern Neck Island still retains most of its land area with wetland loss seen on the coastline of the island.

As previously stated, when comparing Poplar Island to Eastern Neck Island it was important to look at a few key lessons to Eastern Neck Island. However, because Poplar Island's sea-level rise resilient wetlands have only just been constructed there is not much data to show a positive outcome from those design and construction changes. However, research and data found from a variety of reports did solidify the key lessons learned from Poplar Island, as well as qualitative data provide by projector managers at Poplar Island.

Scientists working on Eastern Neck Island have recently began researching ways to adapt to sea-level rise. As such, information on wetland degradation was not complete. The information outlined in the results are suggestions that could be taken at Eastern Neck Island in future wetland development to ensure wetlands are not lost due to sea-level rise.

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